# SYSTEM WITH HOLOGRAPHIC HEAD-UP DISPLAY

This application claims priority to U.S. provisional patent application No. 62/192,871, filed on Jul. 15, 2015, which is hereby incorporated by reference herein in its entirety.

## BACKGROUND

This relates generally to displays and, more particularly, to head-up displays.

Vehicles such as automobiles are sometimes provided with head-up displays. Typical head-up displays project images onto the windshield of a vehicle. A driver of the vehicle can view the projected images while driving. Head-up displays are typically used to display vehicle status information such as speedometer information. Head-up displays allow information to be safely displayed for a driver without requiring the driver to look away from the road ahead.

In conventional head-up displays, a virtual image is created by using a display in a dashboard to project light onto the front windshield of the vehicle at a given angle of incidence, which then reflects the light to the driver's eyes at an angle of reflection that matches the angle of incidence. Since the position of the front windshield is generally a fixed design parameter, the display in the dashboard is precisely positioned to direct light towards the front windshield at a specific angle of incidence so that the light correctly reflects off of the windshield towards the driver.

Traditional head-up displays of this type can place undesirable restrictions on the location of head-up displays in the vehicle. For example, a conventional head-up display may be incompatible with the side window of a vehicle because light reflected off of the side window from a display reasonably mounted within the structure of the vehicle does not reach the user's eyes due to the law of reflection.

It would therefore be desirable to be able to provide improved head-up displays for displaying information for the occupants of a vehicle in a wider range of locations.

## SUMMARY

A vehicle may have windows. A head-up display may produce output that reflects off of one of the windows towards a viewer such as a driver or other occupant in the vehicle.

The head-up display may include a display unit that produces the display output and an optical combiner on a vehicle window that directs the display output towards the viewer. The optical combiner may be a holographic or diffractive optical element or may be an array of angled reflectors such as micromirrors embedded in an index-matching material.

Optical combiners formed from holographic elements may be configured to reflect light at an angle of reflection that, if desired, can be different than the angle of incidence, thereby allowing light to reach a viewer's eyes even when the head-up display reflects light off of a side window in the vehicle. The diffraction order spacing of the holographic optical element may be controlled to reflect a given input angle to a desired output angle.

A holographic optical element may include volume holographic media such as photopolymers or holographic-polymer dispersed liquid crystal in which a reflective hologram has been written (e.g., using the interference of two lasers). The holographic element may be a single layer that has been written with one or more colors or may be multiple layers where each layer has been written with one or more colors.

The holographic optical element may be non-switchable (e.g., may include a permanently encoded hologram) or may be switchable (e.g., may be adjusted by applying an electric field).

Optical combiners formed from angled reflectors may also be configured to direct light towards a viewer even when the optical combiners are formed on side windows of a vehicle. Each reflector in the optical combiner may be angled such that light is reflected off of each individual reflector according to the law of reflection and is directed towards the viewer's eyes.



## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view of an illustrative vehicle with a head-up display in accordance with an embodiment.

FIG. **2** is a schematic diagram of an illustrative vehicle or other system with a head-up display in accordance with an embodiment.

FIG. **3** is a side view of an illustrative head-up display on a side window of a vehicle in accordance with an embodiment.

FIG. **4** is a cross-sectional side view of an illustrative head-up display of the type shown in FIG. **3** having an optical combiner formed from a holographic optical element in accordance with an embodiment.

FIG. **5** is a cross-sectional side view of an illustrative head-up display of the type shown in FIG. **3** having an optical combiner formed from a holographic optical element with multiple layers in accordance with an embodiment.

FIG. **6** is a cross-sectional side view of an illustrative head-up display of the type shown in FIG. **3** having an optical combiner formed from a holographic optical element with multiple layers of switchable diffraction gratings in accordance with an embodiment.

FIG. **7** is a cross-sectional side view of an illustrative head-up display of the type shown in FIG. **3** having an optical combiner formed from an array of reflective structures in accordance with an embodiment.

## DETAILED DESCRIPTION

Systems such as vehicles and other systems may incorporate displays. As an example, a vehicle may have a head-up display that displays vehicle status information such as vehicle speed, direction, and location, fuel gauge information, battery charge level information, status information on vehicle operations such as headlight status, heating and air-conditioner status, seatbelt status, headlight status, media playback information (e.g., current radio station and track information), messages, alerts, augmented-reality-based information, navigation, media, video, conferencing, and other information.

A side view of an illustrative vehicle of the type that may be provided with a head-up display is shown in FIG. **1**. As shown in FIG. **1**, vehicle **10** may include a body such as body **12**. Body **12** may have body panels and other structures that are mounted on a chassis. Interior components in vehicle **10** such as seating for a driver and other vehicle occupants may be supported by the chassis. External components such as wheels **18** may also be mounted to the chassis. The structures that make up body **12** may include metal structures, structures formed from fiber-composite materials such as carbon-fiber materials and fiberglass, plastic, and other materials.